Possible Failure Modes and Emergency Procedures

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This document outlines scenarios for possible system failures and provides a checklist for the recommended emergency response. A list of 4pi emergency contacts is included.

Please note that we do not foresee to make a 4pi deployment without 4pi experts on site. After the commissioning period the new deployment system will be used to make regular z-axis calibrations. 4pi experts will be on-call to assist with any problems that might arise during the regular z-axis calibrations.

A 4pi emergency clamp will be available on-site that can be used to secure the control cables at the pin block when the calibration pole or the z-axis sources are deployed. This emergency clamp can be used to secure and lock out the system in a stable state and transfer the load off the spools, gears, and motor drives. This clamp is only to be used in emergency situations.

The unusual occurrences discussed in this document are:

#1a	Power Outage with z-axis System Deployed
#1b	Power Outage with 4pi System Deployed
#2	Mechanical Motor or Gear Failure
#3	Control Computer Crash
#4	Manual Control Panel Malfunction
#5	Failure of Instrumentation Unit
#6a	Cable or Source Gets Caught in Z-Axis Mode
#6b	Calibration Pole Gets Caught in 4pi Deployment

#1a Power Outage with 4pi System Deployed

Unusual Occurrence: Power outage to the laboratory.

Result:
→ If in motion, 4pi deployment system will stop.
→ Mechanical motor brakes will activate if power is interrupted.
→ System is secured and failsafe in current position.

Recovery Procedure:
1. ❑ Contact shift person, on-site coordinator and 4pi expert. See contact list.
2. ❑ Re-establish power to the laboratory.
3. ❑ Cycle power to the 4pi instrumentation unit.
4. ❑ Power 4pi IR LEDs on. Monitor position with CCD cameras. Determine 4pi position from off-line 4pi IR LED reconstruction.
5. ❑ Restart 4pi control computer and software.
6. ❑ Read 4pi log file to establish last recorded 4pi position.
7. ❑ Make elog entry of reconstructed LED positions and last recorded 4pi position. If in agreement, proceed with 8). Otherwise consult 4pi expert.
8. ❑ Move 4pi calibration pole into vertical home position.
9. ❑ Perform 4pi taring procedure.

#1b Power Outage with Z-Axis System Deployed

Unusual Occurrence: Power outage to the laboratory.

Result:
→ If in motion, deployment system will stop.
→ Mechanical motor brakes will activate if power is interrupted.
→ System is secured and failsafe in current position.

Recovery Procedure:
1. ❑ Contact shift person, on-site coordinator and 4pi expert. See contact list.
2. ❑ Re-establish power to the laboratory.
3. ❑ Cycle power to the 4pi instrumentation unit.
4. ❑ Power 4pi IR LEDs on. Monitor position with CCD cameras. Determine 4pi position from off-line 4pi IR LED reconstruction.
5. ❑ Restart 4pi control computer and software.
6. ❑ Read 4pi log file to establish last recorded z-axis position.
7. ❑ Make elog entry of reconstructed LED positions and last recorded 4pi position. If in agreement, proceed with 8). Otherwise consult 4pi expert.
8. ❑ Retract calibration source into home position.
9. ❑ Perform z-axis taring procedure.

#2 Mechanical Motor or Gear Failure

Unusual Occurrence: One of the motors or gears fails mechanically during the 4pi operation.

Result:

→ If the gears fail, the motor and encoder readings will be different and trigger the controls to stop.
→ If one of the motors fails, the motor will not respond. The lack of feedback will stop the 4pi system.
→ Even if motors fail the system is secured and failsafe in current position.

Recovery Procedure:

1. ❑ Contact shift person, on-site coordinator and 4pi experts. See contact list.
2. ❑ Make elog entry of occurrence including any notable observations.
3. ❑ Use the 4pi emergency clamp to secure the cables above the pin block. At this point the load of the calibration pole is suspended from the emergency lamp and the spools are no longer load-bearing.
4. ❑ Consult with 4pi experts.
5. ❑ Apply temporary seal to cable guide block. See “Temporary Cable Seal Procedure”
6. ❑ Apply nitrogen gas to rotary stage and create over pressure out of 6” stack into glovebox.
7. ❑ Remove window to pent house.
8. ❑ Remove motor enclosure.
9. ❑ Replace damaged gear box or motor. Spares are available on site. Replace motor enclosure.
10. ❑ Seal pent house and thoroughly purge glovebox.
11. ❑ Re-establish normal nitrogen flow in glovebox. Monitor O_2 levels.
12. ❑ Move 4pi system back into vertical home position.
13. ❑ Re-certify the functionality of the 4pi deployment system. See “4pi Certification Procedure”.

#3 Control Computer or Software Crash

Unusual Occurrence: The control computer ceases to function during the 4pi deployment. The control program freezes or the computer crashes.

Result:
→ A crash of the computer or the software will result in an immediate stop of the motor drives. Critical control information as well as the last recorded position will be available in the log file.

Recovery Procedure:
1.❑ Contact shift person, on-site coordinator and 4pi expert. See contact list.
2.❑ Make elog entry of occurrence including any notable observations.
3.❑ Read log file of system and determine system position.
4.❑ Restart computer and/or control program.
5.❑ Move system slowly back into its home position and repeat taring procedure.

#4 Manual Control Panel Malfunction

Unusual Occurrence: The manual control panel malfunctions; it does not issue the correct commands or any commands at all to the motor drives.

Result:
→ The safety of the system and the failsafe interlocks are not compromised if the manual control panel stops functioning. As the manual controls are only used during the assembly of the calibration pole inside the glovebox a malfunction of the control panel will not endanger the detector. All motion steps can also be performed with the computer controls. However, we do not recommend extended operation of the system without manual controls.

Recovery Procedure:
1. ❑ Stop the system.
2. ❑ Reset the controls by pressing 'Stop', then 'Reset'.
3. ❑ If this does not solve the problems with the manual controls, check the cabling in the back of the panel.
4. ❑ Repeat 2.
5. ❑ If this does not solve the problems with the manual controls retract the calibration pole into its home position using the computer controls. Command the computer to take small steps.
6. ❑ When the system is in its home position and secured, shut down the controls, computer, and drives and trouble shoot the control panel. Replace if necessary.
7. ❑ Consult with the 4pi experts and the shift person.
8. ❑ Make an elog entry with incident report of event.

#5 Failure of Instrumentation Unit

Unusual Occurrence: The continuous data readout of the instrumentation fails, or the readings provided by the pressure sensor of the instrumentation unit are in disagreement with the encoder readings and the measured cable lengths of the deployment system. (The thermometer and accelerometers provide auxiliary data for diagnostic purposes. They are not used in the control system interlocks.)

Result:
→ Failure to read the instrumentation unit may trigger an interlock (to be implemented) and stop the system.
→ In any case, we expect the 4pi operator to continuously monitor the data from the instrumentation unit during any motion of the system. If the unit fails or provides erroneous data the operator will stop the system.

Recovery Procedure:
1.❑ Calibration system operator to contact shift person, 4pi expert, and on-site coordinator.
2.❑ Read current position from control software, and confirm with LED CCD reconstruction if possible.
3.❑ Cycle power of instrumentation unit. Take another pressure reading if possible.
4.❑ Make elog entry of occurrence including any notable observations. Note position coordinates.
5.❑ Consult with 4pi expert and detector operator to plan next steps in motion of system.
6.❑ Reset the 4pi controls.
7.❑ Carefully retract the system into its home position.
8.❑ Retract source and cable into glovebox (for z-axis mode) or dismantle the calibration pole (4pi mode).
9.❑ Inspect the instrumentation unit and connectors in glovebox. Replace unit if necessary. Spare is available on site.
10. ❑ Re-certify instrumentation unit in z-axis mode before the next 4pi deployment.

#6a Cable or Source gets Caught in Z-Axis Calibration

Unusual Occurrence: Calibration cable or source get caught during retraction.

Result:

→ The electronic torque limit will automatically shut down the motor drive and stop the system when the torque on the spool exceeds a pre-set limit of *(to be determined)*.

Recovery Procedure:

1. ❑ z-axis operator to contact shift person, 4pi expert, and on-site coordinator.
2. ❑ Investigate and determine cause of unusual occurrence.
3. ❑ Make elog entry of occurrence including any notable observations. Note position coordinates.
4. ❑ Consult with 4pi expert and detector operator to plan next steps in motion of 4pi system.
5. ❑ Reset the 4pi controls.
6. ❑ Slightly lower the z-axis source and cable.
7. ❑ Retract source and cable into the glovebox.
8. ❑ Inspect the cable, source, and source cage.
9. ❑ Discuss incident and conclusions with calibration group and make elog entry with final incident report before re-deploying calibration sources with the z-axis system.

#6b Calibration Pole Gets Caught in 4pi Deployment

Unusual Occurrence: Calibration pole or cables get caught during retraction.

Result:

→ The electronic torque limit will automatically shut down the motor drive and stop the system when the torque on the spool exceeds a pre-set limit of *(to be determined)*.

Recovery Procedure:

1. ❑ 4pi operator to contact shift person and on-site coordinator.
2. ❑ Investigate and determine cause of unusual occurrence.
3. ❑ Make elog entry of occurrence including any notable observations.
4. ❑ Use the 4pi emergency clamp to secure the 4pi cables above the pin block. At this point the load of the calibration pole is suspended from the emergency lamp and the spools are no longer load-bearing.
5. ❑ Consult with 4pi and detector experts to plan next steps in motion of 4pi system.
6. ❑ Reset the 4pi controls.
7. ❑ Move calibration pole back into vertical home position in center of detector.
8. ❑ Retract pole into the glovebox.
9. ❑ Dismantle calibration pole and inspect the cables and the calibration pole.
10. ❑ Discuss incident and conclusions with calibration group and make elog entry with final incident report before re-deploying the 4pi system.

4pi Emergency Contact List

Name	Contact Information		Expertise
Patrick Decowski	work:	+1-510-486-5933	
	email:	decowski@socrates.berkeley.edu	CCD software
Andrew Franck	work:	+1-510-486-6805	mechanics, cabling
	email:	ADFranck@lbl.gov	
Fred Gray	cell:	+1-510-282-7384	control software
	work:	+1-510-642-4057	
	email:	fegray@socrates.berkeley.edu	
Karsten Heeger	cell:	+1-510-207-8489	general system
	work:	+1-510-486-7432	
	home:	+1-510-923-1653	
	email:	kmheeger@lbl.gov	
Herbert Steiner	work:	+1-510-486-6805	general system
	email:	HMSteiner@lbl.gov	